HIGH ENERGY PLATING PROCESS FOR STATIC SEALS

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention generally relates to a process for coating seals with a metallic plating. More specifically, the present invention relates to a high energy, high volume electro-plating process for applying a soft metallic coating to static metallic seals.

Background Information

[0002] Many different types of sealing devices exist for sealing two opposing surfaces. In particular, annular sealing rings are often used to seal opposing surfaces. These annular sealing rings are commonly made of metallic materials such as soft iron, carbon steel, stainless steel, high nickel alloy, Inconel or Nimonic alloys. Typically, conventional seals are manufactured by first cutting or punching "blank" rings of sheet metal out of metallic sheet material, and then bending each of the "blank" rings into the final desired cross-sectional shape using dies (i.e., a transfer press method). Alternatively, these annular sealing rings can be constructed by forming a band, butt welding the ends and then forming the required shape using progressive dies.

[0003] These annular sealing rings can have cross-sections of various shapes. For example, a "C" seal or spring-energized "C" seal is typically an annular seal having a "C" shaped cross-section. Other types of known metallic seals have cross-sections which are parabolic, convoluted, "E" shaped, Y-shaped, omega-shaped (Ω-shaped), or the like. Some of these typical seals are designed to be pressure energized. Additionally, some of these seals are designed to be more resilient than others. In other words, different seals are designed to achieve different sealing characteristics.

[0004] A coating is sometimes applied to these seals to enhance the sealing characteristics. For example, some metallic seals are often coated with a deformable material (e.g., PTFE, gold, silver, copper, and the like) in order to achieve the desired seal integrity. Typically, these metallic seals are coated using time intensive, standard electro-deposition (relatively low energy, relatively low volume) processes that are labor intensive and prohibitive to high-speed manufacturing processes. Specifically, traditional electro-plating processes use a typical current density of around 5-25 ASF (current per unit area, i.e. Amps per Square Foot). Moreover, traditional plating processes for seals are typically discontinuous, which involve submerging a batch of seals in the plating solution (with

mild agitation) and holding them in the plating solution for an extended time (e.g. on the order of 100 minutes) to plate a single batch of seals. Each batch typically includes a plurality of racks with each rack containing a plurality of seals. Furthermore, the seals need to be loaded unloaded from racks before and after each batch is plated, and the seals may need to be rinsed, cleaned, etc. before and/or after the plating process. Finally, depending on the type of plating to be applied to the seals, the plating times for completing a single plating process can vary greatly.

[0005] Traditionally, high sealing integrity (i.e., low leakage) seals have been used in low volume (i.e., small quantities) applications where standard electro-deposition techniques have been adequate from a cost and production rate standpoint. However, when very high production rates (i.e. production of large quantities of seals) ranging from hundreds of thousands to millions of units are desired, these traditional plating techniques are not suitable. Other plating/coating processes may also be ineffective from a cost and production rate standpoint, or suffer from other drawbacks such as a lack in sealing performance due to varying thickness or lack of uniformity of coating, etc.

[0006] In view of the above, it will be apparent to those skilled in the art from this disclosure that there exists a need for an improved high energy plating process for static seals that overcomes the problems in the prior art. This invention addresses these needs in the art as well as other needs, which will become apparent to those skilled in the art from this disclosure.

SUMMARY OF THE INVENTION

[0007] One object of the present invention is to provide a plating process for reliably (consistently) depositing a soft, uniform, deformable, matte metallic coating on static metallic seals in order to ensure or enhance leakage control of the seals.

[0008] Another object of the present invention is to provide a high-volume (mass production), high-energy plating process to automate application of a metallic coating to metallic seals.

[0009] Yet another object of the present invention is to provide a plating process that produces seals providing a sealing integrity on the order of 1×10^{-9} sccs (standard cubic centimeters per second) Helium.

[0010] Yet another object of the present invention is to provide a high energy, high volume plating process for static seals at a relatively low cost per seal.

[0011] Still another object of the present invention is to provide a process for applying a deformable (e.g. smearable), matte finish metallic coating on metallic seals.

[0012] Yet still another object of the present invention is to provide a process that facilitates manual or fully automated insertion/removal of the seals into retention clips and/or carriers with retention clips.

[0013] Yet still another object of the present invention is to provide a process that facilitates continuously moving the seals in a vertical orientation.

[0014] The foregoing objects can basically be attained by providing a high energy plating process for static seals comprising supporting seals on a conveyor and moving the seals through an electro-plating stage. A predetermined quantity of metallic seals is supported at non-sealing surface locations with the metallic seals disposed in series on the conveyor. The conveyor has a predetermined processing path. The metallic seals are continuously moved on the conveyor in series through the electro-plating stage to electro-deposit a metallic coating on the metallic seals using a high current density and a high chemical flow rate. The electro plating stage is part of the predetermined processing path.

[0015] These and other objects, features, aspects and advantages of the present invention will become apparent to those skilled in the art from the following detailed description, which, taken in conjunction with the annexed drawings, discloses a preferred embodiment of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Referring now to the attached drawings which form a part of this original disclosure:

[0017] Figure 1 is a partial, diagrammatic elevational view illustrating a high energy plating process for coating static seals in accordance with a preferred embodiment of the present invention;

[0018] Figure 2 is a side elevational view of one of the seals coated by the process illustrated in Figure 1, as viewed along a central axis in accordance with a preferred embodiment of the present invention;

[0019] Figure 3 is an enlarged partial, longitudinal cross-sectional view of the seal illustrated in Figure 2 as viewed along section line 3-3 of Figure 2, with the seal installed in a joint between a pair of annular, axially facing surfaces of a pair of members that are coupled together;

[0020] Figures 4 is an enlarged, partial side elevational view of a corner portion of the seal illustrated in Figures 2 and 3 identified by the circle 4 in Figure 2;

[0021] Figure 5 is a further enlarged partial, cross-sectional view of the corner portion of the seal illustrated in Figure 4 as viewed along section line 5-5 of Figure 4;

[0022] Figures 6 is an enlarged, partial side elevational view of a side portion of the seal illustrated in Figures 2 and 3 identified by the circle 6 in Figure 2;

[0023] Figure 7 is a partial, cross-sectional view of the portion of the seal illustrated in Figure 6 as viewed along section line 7-7 of Figure 6;

[0024] Figure 8 is an elevational view of one of the carriers used in the process of the present invention, with the seal attachment members of the carrier in the release position;

[0025] Figure 9 is an elevational view of the carrier illustrated in Figure 8, with the seal attachment members of the carrier in the retaining position;

[0026] Figure 10 is an enlarged, partial cross-sectional view of the carrier and seal illustrated in Figures 8 and 9, as seen along section line 10-10 of Figure 9;

[0027] Figure 11 is an elevational view of an alternate carrier usable in the process of the present invention, illustrating the sliding movement of the seal;

[0028] Figure 12 is an elevational view of the carrier and seal illustrated in Figure 11, with the seal retained between the seal attachment members of the carrier;

[0029] Figure 13 is an enlarged, partial cross-sectional view of the carrier and seal illustrated in Figures 11 and 12, as seen along section line 13-13 of Figure 12;

[0030] Figure 14 is an elevational view of another alternate carrier usable in the process of the present invention;

[0031] Figure 15 is an elevational view of another alternate carrier usable in the process of the present invention;

[0032] Figure 16 is an elevational view of another alternate carrier usable in the process of the present invention, with the hinge attachment elements in the open position allowing removal of the seal;

[0033] Figure 17 is a cross-sectional view of the seal and carrier illustrated in Figure 16, as seen along section line 17-17 of Figure 16;

[0034] Figure 18 is an elevational view of the seal and carrier illustrated in Figures 16 and 17, with the hinge attachment elements in the closed, retaining position; and

[0035] Figure 19 is a cross-sectional view of the seal and carrier illustrated in Figures 16-18, as seen along section line 19-19 of Figure 18.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0036] A selected embodiment of the present invention will now be explained with reference to the drawings. It will be apparent to those skilled in the art from this disclosure that the following description of the embodiment of the present invention is provided for illustration only and not for the purpose of limiting the invention as defined by the appended claims and their equivalents.

[0037] Referring initially to Figure 1, a process for depositing a soft (i.e., deformable, smearable), uniform, matte metallic coating on sealing surfaces of metallic seals 10 is illustrated in accordance with a preferred embodiment of the present invention. In the simplest form, the process of the present invention is a high energy, electro-plating process that preferably includes seven steps or stages S100, S200, S300, S400, S500, S600 and S700 in order to produce a relatively large quantity of high quality coated seals 10 in a relatively short period of time. The seals 10 are preferably moved continuously in carriers 11 that are clipped onto a conveyor 12 (e.g. a continuous belt). The carriers 11 are continuously moved through the stages S100, S200, S300, S400, S500, S600 and S700 of the electro-plating process. Each of the carriers 11 holds a predetermined number of seals 10 (e.g. a plurality of seals 10 or a single seal 10). In other words, the conveyor 12 has a predetermined processing path passing through the stages S100, S200, S300, S400, S500, S600 and S700.

[0038] The electro-plating process of the present invention is optimized for seals 10 having the structure (i.e., handling tabs) illustrated herein. In other words, the seals 10 with the handling tabs can cooperate with certain types of carriers, as explained below in more detail. In any case, the carriers 11 of the conveyor 12 support the seals 10 at non-sealing surfaces, as also explained in more detail below. However, it will be apparent to those skilled in the art from this disclosure that the process of the present invention could be utilized with seals having various configurations as needed and/or desired. In any case, the conveyor 12 is preferably designed with a plurality of carriers 11 in order to hold a large quantity of seals 10 at non-sealing areas and to continuously move the seals 10 in an automated manner through the steps S100, S200, S300, S400, S500, S600 and S700 of the

electro-plating process. The structure of the seals 10, for which the process of the present invention is optimized, will be discussed in more detail below.

[0039] The step S100 is preferably a cleaning stage of the electro-plating process, while the step S200 is preferably an initial rinsing stage of the electro-plating process. The step S300 is preferably an under plating stage of the electro-plating process, while the step S400 is preferably an intermediate rinsing stage of the electro-plating process. The step S500 is preferably a top plating stage of the electro-plating process, while the step S600 is preferably a final rinsing stage of the electro-plating process. The step S700 is preferably a drying stage of the electro-plating process. The steps S100, S200, S300, S400, S500, S600 and S700 of the electro-plating process preferably occur in series in ascending numerical order (i.e., S100, then S200, then S300, and so on).

[0040] The steps S100, S200, S300, S400, S500, S600 and S700 are preferably separate steps that each utilizes a separate solution in order to achieve the desired effect of that step. In particular, the cleaning step S100 utilizes a liquid cleaning solution, while the rinsing steps S200, S400 and S600 utilize liquid rinsing solutions. The under and top plating steps S300 and S500 utilize (liquid) electrolytic/chemical solutions, while the step S700 is preferably a separate drying step that uses a drying gas (e.g. air) and/or heat. In other words, the electro-plating process of the present invention is preferably a "wet" process, except for the drying stage S700. However, it will be apparent to those skilled in the art from this disclosure that additional optional drying steps or other steps can be arranged between some or all of the steps S100, S200, S300, S400, S500, S600 and S700 of the electro-plating process if needed and/or desired. Moreover, it will be apparent to those skilled in the art from this disclosure that some or all of the steps S100, S200, S300, S400, S500, S600 and S700 could include several sub-steps (i.e., a plurality of steps), as explained below in more detail.

[0041] Referring still to Figure 1, the conveyor 12 will now be discussed in more detail. The conveyor 12 is relatively conventional, except that the conveyor 12 includes specialized clips 13 (not shown in detail) for manually attaching/removing the carriers 11 thereto/therefrom. The carriers 11 hold/move the seals 10, as mentioned above. The carriers 11 can be designed to hold a plurality of seals 10 (e.g. a dozen seals 10), or a single seal 10 as needed and/or desired. The carriers 11 will be discussed in more detail below. The clips 13 attach the carriers 11 to the conveyor 12. Conveyors such as

conveyor 12 and the clips 13 are relatively well known in the manufacturing arts. Thus, the conveyor 12 and the clips 13 will not be discussed and/or illustrated in detail herein, except as related to the plating process of the seals 10 of the present invention. However, the carriers 11, the conveyor 12 and the clips 13 are especially configured to carry out the present invention, i.e., configured to ensure that the sealing surfaces are properly treated in each step of the process. In particular, the clips 13 and the carriers 11 are arranged and configured to ensure that electrical continuity between the seals 10 and a bus bar (not shown) of the conveyor 12 is sufficient to ensure there is no occurrence of electrical arching, localized overheating or contact point deposition.

[0042] The attachment of the carriers 11 to the conveyor 12 can be achieved manually or in an automated manner. Once the seals 10 are mounted in the carriers 11 and the carriers 11 are clipped to the conveyor 12 via the clips 13, the conveyor 12 continuously moves the seals 10 through the steps S100, S200, S300, S400, S500, S600 and S700 of the electro-plating process. Preferably, the speed of the conveyor 12 is programmable between about six inches per minute and about forty-eight inches per minute (i.e., between about 6"/min and about 48"/min) in a conventional manner. In the illustrated embodiment, the seals 10 are preferably manually mounted/dismounted in the carriers 11. Moreover, in the illustrated embodiment, the carriers 11 are preferably manually clipped/unclipped to/from the clips 13 of the conveyor 12 at the station identified as A in Figure 1.

[0043] Preferably, the picking up and releasing of the seals 10 at the station A is a conventional manual process known in the seal art that is designed such that the conveyor 12 operates as a continuous (carousel type) conveyor. However, it will be apparent to those skilled in the art from this disclosure that the seals 10 can be automatically inserted/removed into/from the carriers 11, and that the carriers 11 can be automatically clipped/unclipped to/from the conveyor 12 if needed and/or desired. In any case the procedure at station A is conventional in the seal art. Thus, the procedure at station A will not be discussed and/or illustrated in detail herein.

[0044] Once the carriers 11 are clipped in place, the conveyor 12 is arranged and configured to continuously move the seals 10 through the steps S100, S200, S300, S400, S500, S600 and S700 of the electro-plating process of the present invention. Preferably, the carriers 11 and the conveyor 12 are arranged and configured to maintain the seals 10 in the vertical orientation in series during the steps S100, S200, S300, S400, S500, S600 and

S700 of the electro-plating process. Specifically, the conveyor 12 is preferably substantially horizontal so that vertically oriented seals 10 can be continuously moved through the steps S100, S200, S300, S400, S500, S600 and S700 of the electro-plating process. However, it will be apparent to those skilled in the art from this disclosure that the seals can be moved in other orientations as needed and/or desired.

[0045] Referring still to Figure 1, during the cleaning step S100, the seals 10 are preferably continuously moved (in the vertical orientation, in series) on the conveyor 12 into a cleaning container or chamber V100. The cleaning chamber V100 is arranged and configured to spray the seals 10 with liquid cleaning solution as the seals 10 move through the chamber V100. The liquid cleaning solution can be an acid such as HCL acid or sulfuric acid. Optionally, the cleaning solution can be electrically charged. Thus, the cleaning stage S100 can be a chemical cleaning stage and/or an electro-cleaning stage. Optionally, the cleaning stage S100 could include an ultrasonic cleaning stage in addition to or instead of the chemical and/or electro cleaning.

[0046] Of course, it will be apparent to those skilled in the art from this disclosure that the cleaning stage S100 could include several separate cleaning sub-stages, and could include optional rinsing stages arranged between the cleaning sub-stages as needed and/or desired. Cleaning techniques for metallic seals are well known in the art. Thus, the cleaning stage S100 will not be discussed and/or illustrated in further detail herein. If rinsing sub-stages are utilized during the cleaning stage S100, each rinsing sub-stage is preferably identical to the rinsing stages S200, S400 and S600, discussed below.

[0047] After the cleaning step S100, the seals 10 are continuously moved (in the vertical orientation, in series) through the initial rinsing step S200. Specifically, the seals 10 are preferably continuously moved (in the vertical orientation, in series) on the conveyor 12 into an initial rinsing container or chamber V200. The initial rinsing chamber V200 is arranged and configured to spray the seals 10 with rinsing solution as the seals 10 move through the chamber V200. The initial rinsing solution is preferably cold, deionized water. Preferably, the rinsing stage S200 includes a pair of rinsing sub-stages. For example, the rinsing stage S200 preferably includes a recirculating rinse followed by a fresh rinse. The water used in the recirculating rinse is water that has already been used during a fresh and/or a recirculating rinse.

[0048] After the initial rinsing step S200, the seals 10 are continuously moved (in the vertical orientation, in series) through the under plating step S300. Specifically, the seals 10 are preferably continuously moved (in the vertical orientation, in series) on the conveyor 12 into a plating container or chamber V300. The plating chamber V300 is arranged and configured to spray the seals 10 with negatively charged electrolytic/chemical solution as the seals 10 move through the chamber V300. Specifically, a rectifier supplies DC current in order to supply metal ions from a metal anode, which are released into the electrolytic/chemical solution. Thus, the metal ions charge the electrolytic/chemical solution and are deposited on the seals 10, as explained below. The fundamentals of electro-plating are well known. Thus, the fundamentals of electro-plating will not be discussed and/or illustrated in detail herein, except as related to the process of the present invention.

[0049] In the simplest form of the present invention, during the under plating stage S300 a single thin metallic coating can be applied to the seals 10. However, the under plating stage S300 can include one, two or more "striking" under plating sub-stages to apply one, two or more thin metallic coatings to the seals 10. If a plurality of "striking" sub-stages are utilized during the under plating stage S300, the seals 10 are preferably rinsed between the sub-stages. In one example of a process in accordance with the present invention, the under plating stage S300 includes a nickel "strike" followed by a rinse and then a tin "strike." A "strike" is a relatively short electro-plating stage that applies a very thin layer of metal to enhance or promote adhesion of the over plating metal applied during step S500, discussed below. The "striking" acts as a surface treatment for the application of a relatively thicker metal plating during the top plating step S500.

[0050] In any case, during each "strike" stage of the under plating step S300, the charged electrolytic/chemical solution is expelled through a gauntlet (i.e., a plurality of strategically placed) of nozzles (not shown) directed at the seals 10 at high velocity to achieve a high chemical flow rate as compared to standard electro-deposition processes. Of course, the chemical flow rate depends on several factors, such as the metal used for the seals 10, the metal used for the anode, the chemical solution, temperature, current density, velocity of the electrolytic/chemical solution, etc. Preferably a current density of between about 5 ASF and about 60 ASF and a spray from the nozzles are used to electro deposit a thin metal coating on the seals 10 during the stage S300. Thus, a relatively low

current density is used during the under plating step S300. A high current density is not needed during this stage because only a very thin (e.g., surface treatment) of metal needs to be electro deposited on the seals 10. Due to the variances in deposition rates for various metals with various chemical solutions, etc., the length of the stage S300 can be varied in order to achieve a substantially constant production rate.

[0051] The "length" of the stage S300 refers to the length of the chamber V300. The longer the chamber V300, the longer time the seals 10 will be exposed to the charged electrolytic/chemical solution from the nozzles (assuming a constant speed for the conveyor 12). Of course, if several striking sub-stages are used during the stage S300, the vessel V300 will be divided into a corresponding number of sub-vessels for each sub-stage. In any case, preferably, the seals 10 are sprayed with the charged electrolytic/chemical solution(s) from nozzles along a predetermined length or lengths of the chamber V300. Adjustment of the length of the chamber V300 (or the sub-chambers if more than one strike is desired) is the primary adjustment mechanism to adjust the under plating step S300 for different coating/base metals, etc. However, it will be apparent to those skilled in the art from this disclosure that other variables during the stage S300 can be slightly modified as needed and/or desired in order to achieve the desired production rate for a given seal metal, coating metal, coating thickness, etc. In any case, the process of the present invention can be utilized to achieve a substantially constant production rate for coated seals 10, regardless of the material of the seals 10.

[0052] The electrolytic/chemical solution(s) is designed to cooperate with the anode material (e.g., nickel and/or tin) to deposit the desired metallic coating, at the desired thickness on the seals 10. A pure metal or pure metal alloy is preferably utilized for the anode material. For example, the anode material could be tin, tin alloy, lead, gold, silver, silver alloy, nickel, copper or indium. In this embodiment, the seals 10 can be constructed of any suitable material such as the metallic materials that are well known in the art. For example, the seals 10 can be constructed of 300 Series Stainless Steel, Inconel X-750, Waspaloy, or any other material appropriate for the particular operating conditions. The precise chemical solution is not critical to the present invention. Thus, it will be apparent to those skilled in the art from this disclosure that any suitable electrolytic/chemical solution could be used during the stage S300 as needed and/or desired. In other words, the type of chemical solution needed in order to create certain metal coatings by the process of

the present invention are well known. For example, hydrochloric acid can be utilized in conjunction with nickel metal during a nickel strike.

[0053] After the under plating step S300, the seals 10 are continuously moved (in the vertical orientation, in series) through the intermediate rinsing step S400. Specifically, the seals 10 are preferably continuously moved (in the vertical orientation, in series) on the conveyor 12 into an intermediate rinsing container or chamber V400. The intermediate rinsing chamber V400 is arranged and configured to spray the seals 10 with rinsing solution as the seals 10 move through the chamber V400. The intermediate rinsing solution is preferably cold, deionized water. Preferably, the rinsing stage S400 includes a pair of rinsing sub-stages. For example, the rinsing stage S400 preferably includes a recirculating rinse followed by a fresh rinse. The water used in the recirculating rinse is water that has already been used during a fresh and/or a recirculating rinse.

[0054] After the intermediate rinsing step S400, the seals 10 are continuously moved (in the vertical orientation, in series) through the top plating step S500. Specifically, the seals 10 are preferably continuously moved (in the vertical orientation, in series) on the conveyor 12 into a plating container or chamber V500. The plating chamber V500 is arranged and configured to spray the seals 10 with charged electrolytic/chemical solution as the seals 10 move through the chamber V500. Specifically, a rectifier supplies DC current in order to supply metal ions from a metal anode, which are released into the electrolytic/chemical solution. Thus, the metal ions charge the electrolytic/chemical solution and are deposited on the seals 10.

[0055] The step S500 is similar to the step S300. However, the step S500 is significantly longer than the step S300 (i.e., preferably at least ten times longer than each strike sub-stage of the stage S300) and deposits significantly more of a different coating on the seals 10, as explained below in more detail. Moreover, the charged electrolytic/chemical solution is expelled through a gauntlet (i.e., a plurality of strategically placed) of nozzles (not shown) directed at the seals 10 at high velocity to achieve a high chemical flow rate as compared to standard electro-deposition processes. Of course, the chemical flow rate depends on several factors, such as the metal used for the seals 10, the metal used for the anode, the chemical solution, temperature, current density, velocity of the electrolytic/chemical solution, etc. Preferably, a current density of between about 200 ASF and about 1000 ASF and a high velocity spray from the nozzles

are used to electro deposit a top plating metal coating on the seals 10 during the stage S500. Due to the variances in deposition rates for various metals with various chemical solutions, etc., the length of the stage S500 can be varied in order to achieve a substantially constant production rate.

[0056] In one example of a process in accordance with the present invention, the top plating stage S500 applies tin plating to the seals 10. In this process, a single nickel strike is utilized during the under plating stage S300, and the tin plating is applied to the nickel under plating applied during the under plating stage S300. Alternatively, Silver plating can be applied over a single nickel strike. In another example of a process in accordance with the present invention, the top plating stage S500 applies a tin/lead plating to the seals 10. In this process, a nickel strike followed by a rinse and then a tin strike should be included in the under plating stage S300. The tin/lead plating is then applied to the tin coating of the seals 10 using a current density of about 200 ASF during the top plating stage S500. Free methane sulfonic acid can be used with stannous tin and lead during such a top plating stage S500.

[0057] The "length" of the stage S500 refers to the length of the chamber V500. The longer the chamber V500, the longer time the seals 10 will be exposed to the charged electrolytic/chemical solution from the nozzles (assuming a constant speed for the conveyor 12). Preferably, the seals 10 are continuously sprayed with the charged electrolytic/chemical solution from the nozzles along the entire length of the chamber V500. Adjustment of the length of the chamber V500 is the primary adjustment mechanism to adjust the top plating step S500 for different coating/base metals, etc. However, it will be apparent to those skilled in the art from this disclosure that other variables during the stage S500 can be slightly modified as needed and/or desired in order to achieve the desired production rate for a given seal metal, coating metal, coating thickness, etc. In any case, the process of the present invention can be utilized to achieve a substantially constant production rate for coated seals 10, regardless of the material of the seals 10.

[0058] The electrolytic/chemical solution used during the step S500 is designed to cooperate with the anode material to deposit the desired metallic coating, at the desired thickness on the seals 10. A pure metal or pure metal alloy is preferably utilized for the anode material. For example, the anode material could be tin, tin alloy, lead, gold, silver,

silver alloy, nickel, copper or indium. The precise chemical solution is not critical to the present invention. Thus, it will be apparent to those skilled in the art from this disclosure that any suitable electrolytic/chemical solution could be used during the stage S500 as needed and/or desired. In other words, the type of chemical solution needed in order to create certain metal coatings by the process of the present invention are well known.

[0059] After the top plating step S500, the seals 10 are continuously moved (in the vertical orientation, in series) through the final rinsing step S600. Specifically, the seals 10 are preferably continuously moved (in the vertical orientation, in series) on the conveyor 12 into a final rinsing container or chamber V600. The final rinsing chamber V600 is arranged and configured to spray the seals 10 with rinsing solution as the seals 10 move through the chamber V600. The final rinsing solution is preferably cold, deionized water. Preferably, the rinsing stage S600 includes a pair of rinsing sub-stages. For example, the rinsing stage S600 preferably includes a recirculating rinse followed by a fresh rinse. The water used in the recirculating rinse is water that has already been used during a fresh and/or a recirculating rinse.

[0060] After the final rinsing step S600, the seals 10 are continuously moved (in the vertical orientation, in series) through the drying step S700. Specifically, the seals 10 are preferably continuously moved (in the vertical orientation, in series) on the conveyor 12 into a drying container or chamber V700. The drying chamber V700 is arranged and configured to spray the seals 10 with a drying gas such as air as the seals 10 move through the chamber V400. The drying chamber V700 could also use heat in addition to or instead of the drying gas if needed and/or desired. After step S700, the plating process of the present invention is complete. Due to the carousel design of the conveyor 12, the carriers with the finished, coated seals 10 are then sent back to the station A to be unloaded and to have a new batch of uncoated seals 10 loaded onto the conveyor 12.

[0061] The under plating step/stage S300, the intermediate rinsing step/stage S400 and the top plating step/stage S500 together form parts of an overall "electro-plating stage" of the predetermined processing path of the present invention. Of course, it will be apparent to those skilled in the art from this disclosure that the electro-plating stage could include additional/fewer steps as needed and/or desired. In any case, the electro-plating stage of the present invention preferably includes at least one plating step/stage that electro-

deposits a coating metal on the seals 10 using a high current density and high chemical flow rate as described herein in accordance with the present invention.

[0062] Preferably, the process of the present invention is designed such that the primary variables are speed of the conveyor 12, seal material, anode material, electrolytic/chemical solution, and the length of the stages S100, S200, S300, S400, S500, S600 and S700. In other words, the remaining variables of the process such as temperature, current density, electrolytic/chemical solution flow velocity, nozzle structure, etc. are preferably kept substantially constant. However, the speed of the conveyor is preferably programmed to a predetermined (i.e., substantially constant) level or speed consistent with the operations at the station A. Thus, if the desired coating thickness, coating material or seal material is changed, the length of at least the stages S300 and/or S500 and the electrolytic/chemical solution would preferably be changed in order to achieve the desired product at the pre-programmed speed. Thus, the process of the present invention is relatively simple.

[0063] Referring now to Figures 2-7, the metallic seals 10 will be discussed in more detail. The seals 10 are identical to each other. Thus, only one of the seals 10 will be discussed and illustrated in detail herein. Because the metallic coating applied to the seals 10 is so thin, the metallic coating will not be illustrated in detail herein. In the illustrated embodiment, the metallic seal 10 is designed to be externally pressure energized to maintain a seal between a pair of members 14 and 16. More specifically, the seal 10 is an annular seal designed to seal a pair of axially facing annular surfaces 18 and 20 of the members 14 and 16, respectively. While the seal 10 is illustrated as being externally pressurized, it will be apparent to those skilled in the art from this disclosure that the seal 10 could be internally pressurized as needed and/or desired. Moreover, it will be apparent to those skilled in the art from this disclosure that the seals 10 could be designed as radial seals with radially facing sealing surface and/or with various cross-sectional shapes, as needed and or desired for certain sealing applications. In other words, the seals 10 illustrated herein are merely an example suitable for the plating process of the present invention.

[0064] The metallic seal 10 is preferably substantially rectangular shaped with rounded corners as viewed along a central axis O. However, it will be apparent to those skilled in the art from this disclosure that the seal 10 could have various other

configurations (i.e., shapes, sizes, orientations, etc.), as needed and/or desired. For example, the seal 10 could have a circular configuration or another configuration. Moreover, it will be apparent to those skilled in the art from this disclosure that the seals 10 illustrated herein may be particularly useful in industries such as the data storage, semi-conductor, automotive and power-generation industries. However, it will be apparent to those skilled in the art from this disclosure that the seals 10 could be used in other industries where high production rates and the need for high reliability sealing coverage is needed and/or desired. For example, the seal 10 could be utilized in the aerospace industry or any other industry that requires the functionality of the seal 10.

[0065] Referring still to Figures 2-7, the seal 10 basically includes a first annular leg portion 22, a second annular leg portion 24 and an annular connecting portion 26. The first and second leg portions 22 and 24 are connected to each other by the connecting portion 26 to form a modified C-shaped cross-sectional shape, as best seen in Figures 3, 5 and 7. Specifically, the second leg portion 24 includes an annular flange 28 with a plurality of tabs 30 extending radially from the flange 28 relative to the central axis O in order to form the modified C-shaped cross-sectional shape.

[0066] The tabs 30 are arranged at the rounded corners of the rectangular shaped seal 10. The tabs 30 project further in a radial direction than adjacent parts of annular flange 28. The tabs 30 can be used to handle the seals 10 at the station A, to move the seals 10 on the conveyor 12 and/or during installation of the seals 10. Specifically, modified carriers can cooperate with the tabs 30 to hold the tabs 30 (i.e., at non-sealing surfaces of the seals 10), as discussed below. In the illustrated embodiment, the seals 10 can be handled manually at the station A via the tabs 30. However, it will be apparent to those skilled in the art from this disclosure that the handling of the seals 10 (i.e., at the tabs 30) can be fully automated to automatically pick-up and drop off the seals 10 at the station A, if needed and/or desired.

[0067] The leg portions 22 and 24, the connecting portion 26 and the flange 28 are all concentric about the central axis O of the seal 10. Thus, the leg portions 22 and 24, the connecting portion 26 and the flange 28 all extend around the central axis O of the seal 10. The tabs 30 are circumferentially spaced around the seal 10, while the flange 28 is continuous around the circumference of the seal 10. Due to the arrangement of the flange 28 and the tabs 30, a transverse center plane P divides the seal 10 into two asymmetrical

halves. The center plane P passes through the central axis O and is preferably substantially perpendicular to the central axis O. The structure of the flange 28 and the tabs 30 will be discussed in more detail below.

[0068] As best seen in Figure 7, the central annular portion 26 includes a first end 32, a second end 34, an outer convex connecting surface 36 and an inner concave connecting surface 38. The outer and inner connecting surfaces 36 and 38 are curved surfaces. The outer and inner connecting surfaces 36 and 38 extend between the first and second ends 32 and 34 of the central annular portion 26. The first leg portion 22 extends from the first end 32 of the central annular portion 26, while the second leg portion 24 extends from the second end 34 of the central annular portion 26. The carriers 11 preferably contact the curved inner connecting surface 38, as explained below in more detail.

[0069] The first annular leg portion 22 includes an annular first free end 42, a first annular convex outer sealing surface 44 and a first concave interior surface 46. The first sealing surface 44 and the first interior surface 46 are curved surfaces. The first sealing surface 44 extends from the first free end 42 of the first annular leg portion 22 to the first end 32 of the central annular portion 26 (i.e., to the outer connecting surface 36). The first interior surface 46 also extends from the first free end 42 of the first annular leg portion 22 to the first end 32 of the central annular portion 26 (i.e., to the inner connecting surface 36). The first sealing surface 44 lies in a first sealing plane S_1 that is substantially parallel to the center plane P of the seal 10. In particular, a first sealing line L_1 of the first sealing surface 44 lies in the first sealing plane S_1.

[0070] The second annular leg portion 24 includes an annular second free end 52, a second annular convex outer sealing surface 54 and a second concave interior surface 56. The second sealing surface 54 and the second interior surface 56 are curved surfaces. The second free end 52 includes the annular flange 28 and the tabs 30. The second sealing surface 54 extends from the second free end 52 of the second annular leg portion 24 to the second end 34 of the central annular portion 26 (i.e., from the annular flange 28 to the outer connecting surface 36). The second sealing surface 54 lies in a second sealing plane S_2 that is substantially parallel to the center plane P of the seal 10. In particular, a second sealing line L_2 of the second sealing surface 54 lies in the second sealing plane S_2.

[0071] If the seal 10 is compressed between the annular surfaces 18 and 20 of the members 14 and 16 and/or when the seal 10 is pressure energized, a pair of conventional

sealing dams (not shown) are formed that lie in the first and second sealing planes S_1 and S_2. Thus, the first and second sealing planes S_1 and S_2 are preferably substantially parallel to each other.

[0072] The annular flange 28 basically includes an annular outer flat surface 62 and an annular inner flat surface 64 with an annular free edge of the second free end 52 extending therebetween. The outer and inner flat surfaces 62 and 64 of the annular flange 28 are preferably substantially parallel to each other and substantially parallel to the center plane P. Moreover, the outer and inner flat surfaces 62 and 64 of the annular flange 28 are preferably offset from the second sealing plane S_2 in the axial direction toward the first sealing plane S_1. In this embodiment, the annular flange 28 of the second free end 52 extends in a radial direction away from central annular portion 26 at least as far as the first free end 42 of the first leg portion 22. More specifically, the annular flange 28 with the tabs 30 preferably extends in a radial direction away from central annular portion 26 beyond the first free end 42 of the first leg portion 22 such that the annular free edge of the second free end 52 is located completely radially beyond the first free end 42 of the first leg portion 22, as best seen in Figures 3, 4, 6 and 7.

[0073] The second free end 52 extends outwardly in the radial direction relative to the remainder of the annular flange 28 in order to form the tabs 30. In other words, the outer and inner flat surfaces 62 and 64 (i.e., at the tabs 30) of the flange 28 extend radially beyond the adjacent parts of the annular flange 28. Thus, the tabs 30 preferably extend radially further than adjacent parts of the entire seal 10. The seal 10 preferably has a constant cross-sectional shape around its periphery, except at the corners where the tabs 30 are located.

[0074] The tabs 30 preferably have identical overall shapes as seen in Figure 2. Moreover, the tabs 30 are preferably peripherally spaced from each other such that one of the tabs 30 is located at each corner portion. Optionally, one or more of the tabs 30 can have an opening or slot formed therein to facilitate manual or automated handling. Of course, it will be apparent to those skilled in the art from this disclosure that the tabs 30 can have other configurations and could be different from each other as needed and/or desired. In any case, the tabs 30 are preferably arranged and configured to facilitate the process of the present invention when certain carriers are desired, providing an area to contact with the seals 10 at non-sealing areas (surfaces).

[0075] While the process of the present invention is optimized with seals 10 having the handling tabs 30, it will be apparent to those skilled in the art from this disclosure that the process of the present invention can be used with seals absent handling tabs such as conventional c-seals or seals having other cross-sectional shapes. In such arrangements, the carriers 11 should be arranged and configured to handle non-sealing surfaces of the seals (i.e., other than the tabs 30). For example, if the seals 10 illustrated herein did not have the tabs 30, the carriers 11 should be arranged and configured to hold the seals 10 on the internal curved surfaces 38, 46 and/or 56, or at any other non-sealing surface(s).

[0076] The seal 10 performs the sealing function between the members 14 and 16 in a conventional manner, i.e., in a manner substantially identical to conventional C-seals on the market. In other words, the manner in which the first and second sealing surfaces 44 and 54 form a seal between the annular surfaces 18 and 20 of the members 14 and 16, respectively, is conventional. Thus, the manner in which the seal 10 seals will not be discussed and/or illustrated in details herein. However, the seal 10 is processed in high volume (mass produced) with the coating to enhance or ensure the sealing function will be consistently carried out to the desired level of reliability.

[0077] Referring now to Figures 8-10, the carriers 11 will now be explained in more detail. The carriers 11 are identical to each other. Thus, only one of the carriers 11 will be discussed and illustrated in detail herein. Each carrier 11 can be designed to carry/hold a single seal 10 or a plurality of seals 10. The carrier 11 basically includes a conveyor attachment portion 70 and at least a pair of seal attachment members 72. Each of the pair of attachment members 72 includes a projection 74 designed to contact the curved interior of the seal 10. Thus, the carrier 11 does not utilize the tabs 30. The attachment members 72 are arranged and configured to move together and hold the seals 10 therebetween, and to move apart to release the seals 10. The conveyor attachment portion 70 includes a projecting section 76 and a transverse section 78. The projecting section 76 is clipped to the conveyor 12 via one of the clips 13 in a conventional manner.

[0078] If the carrier 11 is designed to hold a single seal 10, the carrier 11 should have a single, flat conveyor attachment portion 70 with a single projecting section 76 and two seal attachment members 72 movably coupled to the transverse section 78. However, if the carrier 11 is designed to hold a plurality of seals 10, the carrier 11 should have a number of transverse sections 78 corresponding to the number of seals 10 that will be

coupled thereto, with a pair of the seal attachment portions 72 coupled to each transverse section 78. The transverse sections 78 should be fixedly coupled together in such an arrangement. Moreover, in such an arrangement, each carrier 11 should have at least two projecting sections 76 extending from the transverse sections 78 that are coupled together. Whether the carriers 11 hold a single seal 10 or a plurality of seals 10 is not critical to the process of the present invention.

ALTERNATE CARRIERS

[0079] Referring to Figures 11-13, an alternate carrier 211 is illustrated for use in the process of the present invention. While only one carrier 211 is illustrated herein, it will be apparent to those skilled in the art that a plurality of carriers 211 would be used in the process of the present invention. Each carrier 211 can be designed to carry/hold a single seal 10 or a plurality of seals 10. The carrier 211 basically includes a conveyor attachment portion 270 and at least a pair of seal attachment members 272. Each of the pair of attachment members 272 includes a projection 274 designed to contact the curved interior of the seal 10. Thus, the carrier 211 does not utilize the tabs 30. The attachment members 272 are arranged and configured to hold the seals 10 therebetween. In particular, the projections 274 are preferably spaced a slightly smaller distance from each other than the corresponding dimension of the seals 10 in order to frictionally retain the seals 10 when they are slid in between the attachment members 272. The conveyor attachment portion 270 includes a projecting section 276 and a transverse section 278. The projecting section 276 is clipped to the conveyor 12 via one of the clips 13 in a conventional manner.

[0080] If the carrier 211 is designed to hold a single seal 10, the carrier 211 should have a single, flat conveyor attachment portion 270 with a single projecting section 276 and two seals attachment members 272 fixedly coupled to the transverse section 278. However, if the carrier 211 is designed to hold a plurality of seals 10, the carrier 211 should have a number of transverse sections 278 corresponding to the number of seals 10 that will be coupled thereto, with a pair of the seal attachment portions 272 fixedly coupled to each transverse section 278. The transverse sections 278 should be fixedly coupled together in such an arrangement. Moreover, in such an arrangement, each carrier 211 should have at least two projecting sections 276 extending from the transverse sections 278 that are coupled together. Whether the carriers 211 hold a single seal 10 or a plurality of seals 10 is not critical to the process of the present invention.

[0081] Referring to Figure 14, an alternate carrier 311 is illustrated for use in the process of the present invention. While only one carrier 311 is illustrated herein, it will be apparent to those skilled in the art that a plurality of carriers 311 would be used in the process of the present invention. The carrier 311 is formed as excess sheet material coupled to the tabs 30 of the seals 10 by narrow sections 370. In other words, the carrier 311 is integrally formed with one of the seals 10. The excess sheet material remains from the initial manufacturing of the uncoated seals 10. The narrow sections 370 are preferably arranged and configured to be broken off from the tabs 30 after the plating process of the present invention.

[0082] Referring to Figure 15, an alternate carrier 411 is illustrated for use in the process of the present invention. While only one carrier 411 is illustrated herein, it will be apparent to those skilled in the art that a plurality of carriers 411 would be used in the process of the present invention. The carrier 411 is formed as excess sheet material coupled to one of the tabs 30 of the seal 10 by narrow sections 470. In other words, the carrier 411 is integrally formed with one of the seals 10. The excess sheet material remains from the initial manufacturing of the uncoated seals 10. The narrow sections 470 are preferably arranged and configured to be broken off from the tab 30 after the plating process of the present invention.

[0083] Referring now to Figures 16-19, an alternate carrier 511 is illustrated in accordance with the present invention. While only one carrier 511 is illustrated herein, it will be apparent to those skilled in the art that a plurality of carriers 511 would be used in the process of the present invention. Each carrier 511 can be designed to carry/hold a single seal 10 or a plurality of seals 10. The carrier 511 basically includes a conveyor attachment portion 570 and at least a pair of seal attachment members 572. Each of the pair of attachment members 572 includes a pair of hinged seal attachment elements 574 designed to hold a respective pair of the tabs 30 of the seal 10. Thus, the carrier 511 does utilize the tabs 30. The hinged attachment elements 574 are arranged and configured to hold the seals 10 therebetween (i.e., the tabs 30) in one position and to release the tabs 30 when moved to another position as seen in Figures 17 and 19. The conveyor attachment portion 570 includes a projecting section 576 and a transverse section 578. The projecting section 576 is clipped to the conveyor 12 via one of the clips 13 in a conventional manner.

[0084] If the carrier 511 is designed to hold a single seal 10, the carrier 511 should have a single, flat conveyor attachment portion 570 with a single projecting section 576 and two seals attachment members 572 fixedly coupled to the transverse section 578. However, if the carrier 511 is designed to hold a plurality of seals 10, the carrier 511 should have a number of transverse sections 578 corresponding to the number of seals 10 that will be coupled thereto, with a pair of the seal attachment portions 572 fixedly coupled to each transverse section 578. The transverse sections 578 should be fixedly coupled together in such an arrangement. Moreover, in such an arrangement, each carrier 511 should have at least two projecting sections 576 extending from the transverse section 578 that are coupled together. Whether the carriers 511 hold a single seal 10 or a plurality of seals 10 is not critical to the process of the present invention.

[0085] The terms of degree such as "substantially", "about" and "approximately" as used herein mean a reasonable amount of deviation of the modified term such that the end result is not significantly changed. For example, these terms can be construed as including a deviation of at least ± 5% of the modified term if this deviation would not negate the meaning of the word it modifies.

[0086] While only a selected embodiment has been chosen to illustrate the present invention, it will be apparent to those skilled in the art from this disclosure that various changes and modifications can be made herein without departing from the scope of the invention as defined in the appended claims. For example, the present invention could also be applied to circular seals also, i.e., a circular seal with or without tabs and/or a flange. Furthermore, the foregoing description of the embodiment according to the present invention is provided for illustration only, and not for the purpose of limiting the invention as defined by the appended claims and their equivalents. Thus, the scope of the invention is not limited to the disclosed embodiment.